

1. Determine Lewis structures of following chemical species (2 points each)
  - 1)  $\text{CH}_3\text{CN}$
  - 2)  $\text{OPCl}_3$
  - 3)  $\text{PBr}_5$
  - 4)  $\text{N}_2\text{H}_4$
2. Determine Lewis structures of following polyatomic ions. Include all resonance structures and formal charges, where appropriate (2 points each)
  - 1)  $\text{HSO}_4^-$
  - 2)  $\text{SO}_3^{2-}$
  - 3)  $\text{BrO}_3^-$
  - 4)  $\text{N}_2\text{O}$
3. Determine the molecular shape and the ideal bond angles of each of the following: (2 points each)
  - 1)  $\text{SO}_2$
  - 2)  $\text{I}_3^+$
  - 3)  $\text{ClF}_4^-$
  - 4)  $\text{ICl}_4^-$
4. Name the types of attractive forces that will contribute to the interactions among atoms, molecules, or ions in the following substances. Indicate the one(s) you expect to predominate (2 points each).
  - 1) Ne
  - 2) KF
  - 3) HI
  - 4)  $\text{BaCl}_2$
  - 5)  $\text{H}_2\text{O}$
5. Predict bond angles for  $\text{BCl}_3$ ,  $\text{SF}_4$  and  $\text{SnCl}_4$ . Which of these molecules, if any, has a dipole moment? (Sn,  $Z=50$ ) (4 points)

6. Arrange the following bonds in order of increasing length (shortest first) and increasing strength (weakest first). State the factors responsible for the position of each bond in your sequences: C-C, C=O, C=C, C-H, C-Cl. (8 points)
- 2) Give the bond order of each species (4 points)
- 3) Predict which species are paramagnetic (2 points)
7. When one electron is added to an oxygen molecule, a superoxide ion ( $\text{O}_2^-$ ) is formed. The addition of two electrons gives a peroxide ion ( $\text{O}_2^{2-}$ ). Removal of an electron from  $\text{O}_2$  leads to  $\text{O}_2^+$ .
- 1) Give the molecular electron configuration for each of following species:  $\text{O}_2^+$ ,  $\text{O}_2$ ,  $\text{O}_2^-$ ,  $\text{O}_2^{2-}$  (4 points)
8. Determine Lewis structure of  $\text{ClO}_3^-$  and  $\text{ClO}_2^-$  and describe the bonding for each of these anions including delocalized  $\pi$  bonds. (6 points)

9. Use molecular orbital diagram to explain the trend in bond energies for the following diatomic molecules:  $N_2 = 942 \text{ kJ/mol}$ ,  $O_2 = 495 \text{ kJ/mol}$ , and  $F_2 = 155 \text{ kJ/mol}$  (6 points).
10. The band gap of silicon is  $105 \text{ kJ/mol}$ . What is the minimum wavelength of light that can promote an electron from the valence band to the conduction band? (4 points)
11. There are nine important hydrogen-bonding interactions. One of them is  $O \cdots HO$ . Draw the other eight (8 points).
12. Arrange the following liquids in order of increasing viscosity, and state the factors that determine the ranking: n-butanol  $CH_3CH_2CH_2CH_2OH$ , n-pentane  $C_5H_{12}$ , propane-1,3-diol  $HOC_3H_6OH$ , and 2,2-dimethylpropane  $(CH_3)_4C$  (6 points).

13. Draw the unit cell of the NaCl crystal and determine the number of nearest neighbors of opposite charge for each ion in this unit cell (4 points).

1) Use this information to sketch the phase diagram of nitrogen (6 points)

2) What is maximum pressure at which solid N<sub>2</sub> can sublime? (4 points)

14. The following table gives several important points on the pressure-temperature diagram of nitrogen (N<sub>2</sub>)

	P (atm)	T (K)
Triple point	0.123	63.15
Critical point	33.3978	126.19
Normal boiling point	1.0	77.35
Normal melting point	1.0	63.29

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$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

$$N_A = 6.022 \times 10^{23}$$